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DOCUMENTATION OF DECISION-AIDING SOFTWARE:

OPINT FUNCTIONAL DESCRIPTION

DECISIONS AND DESIGNS INC.

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OPINT FUNCTIONAL DESCRIPTION
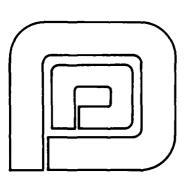
by

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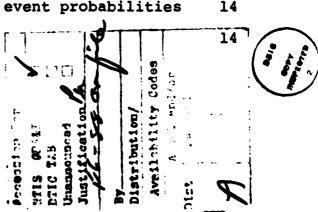
FIGURES

OPINT: FUNCTIONAL DESCRIPTION

1.0 INTRODUCTION

1.1 Purpose of the Functional Description

This functional description provides a technical delineation of the specific functions that OPINT must perform. It serves as a formal basis for mutual understanding between the functional designer of the system and the software development personnel. Together with the OPINT System Specification, it serves as the basic documentation for systems development and implementation.

1.2 References

1.2.1 Barclay, Scott, et al. Handbook for Decision Analysis. Technical Report 77-6-30. McLean, Virginia: Decisions and Designs, Inc., September 1977.

1.2.2 Amey, Dorothy M.; Feuerwerger, Phillip H.; Gulick, Roy M. Documentation of Decision-Aiding Software: OPINT Users Manual. McLean, Virginia: Decisions and Designs, Inc., April 1979.

1.2.3 Amey, Dorothy M.; Feuerwerger, Phillip H.; Gulick, Roy M. Documentation of Decision-Aiding Software: OPINT Systems Specification. McLean, Virginia: Decisions and Designs, Inc., April 1979.

1.3 Terms and Abbreviations

1.3.1 OPINT - OPINT, the name of the system, is an abbreviation for Operations and Intelligence, reflecting the system's major area of applicability.

1.3.2 Terms - Standard mathematical notations and decision-analytic terminology are used throughout this functional description. Decision-analytic terms are defined when they are first encountered. Reference 1.2.1 provides more detail on decision analysis, should it be desired.

2.0 SYSTEM SUMMARY

2.1 System Description

OPINT is a decision-analytic, model-building software system. Its general purpose is to aid decision makers by providing them a capability to construct, store, retrieve, exercise, and refine decision-analytic models of complex decision problems they face.

The OPINT decision model is the organizing framework for information processing. Decision analysis is the methodological tool with which the decision maker defines and exercises the OPINT model to evaluate decision alternatives pertaining to the problem.

The overall objective of OPINT is to ensure that the ultimate decision choice is a coherent one: a choice that is consistent with the decision maker's own value structure and belief about the likelihood of future events that will affect the decision outcome. For a complete description of the purpose and use of OPINT, see OPINT Users Manual, Reference 1.2.2.

2.2 Design Objectives

The system is designed to be used interactively by end users who are relatively unsophisticated with respect to computer technology. Accordingly, the design satisfies two human-factors objectives: OPINT is a menu-driven system and is generally forgiving of procedural errors by the user.

In addition, to facilitate the production of the program specification and coding necessary to implement OPINT

at a physical site, the system is designed in a hierarchi-
cally structured and modular fashion. The logical structure
of OPINT is contained in OPINT Systems Specification,
Reference 1.2.3.

3.0 DETAILED CHARACTERISTICS

The fundamental product of OPINT is the decision model. The OPINT system enables the user to create, store, retrieve, exercise, and refine decision models interactively.

All of the specific functions that OPINT performs are related to the OPINT decision model. Therefore, in order to establish a frame of reference for understanding the OPINT functions, it is necessary to begin with a detailed description of the format, inputs, and outputs of the decision model. A description of the specific functions that OPINT performs appears in Section 4.0.

3.1 Model Description

Each decision model created by the user has a unique label, and each is constructed by using the same generic format. The model format is shown graphically in Figure 3-1. The format always consists of all of the following elements which, when completely specified, uniquely define an OPINT decision model.

3.1.1 **The decision** - A short label, D, defining the decision problem. This label is also applied to the decision model and is used to store and retrieve the model.

3.1.2 **Decision alternatives** - A list of the n decision alternatives $(D_1, D_2, \ldots D_n)$ available to the decision maker. Each alternative is appropriately labeled.

3.1.3 **An uncertain future event** - A key uncertain event, E, appropriately labeled, that will influence the eventual outcome of the decision. The uncertain event is attached to each of the decision alternatives.

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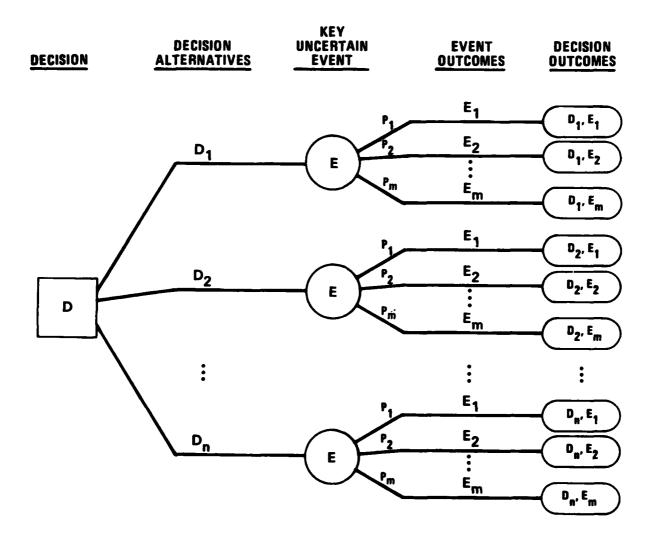
Figure 3-1

DECISION MODEL FORMAT

3.1.4 <u>Event outcomes</u> - A list of the m discrete event outcomes $(E_1, E_2, \ldots E_m)$, each appropriately labeled, that together define the universe of possibilities regarding the occurrence of the future event.

3.1.5 <u>Event probabilities</u> - A vector of m probabilities $(p_1, p_2, \ldots p_m)$ that are associated with the m event outcomes, such that p_i represents the probability that event E_i will occur. A probability is a measure of uncertainty. It is a number between 0 and 1, inclusive, that represents the extent to which an individual believes a future event will occur. However, in this specification, probabilities are usually expressed as a percentage of certainty, e.g., as 40% vice 0.4.

3.1.6 <u>Decision outcomes</u> - The elements discussed thus far define n x m possible decision outcomes. Each decision outcome (D_j, E_k) is a paired combination of one decision alternative with one event outcome.

The remaining three elements of the model format are used to specify the relative consequences associated with the decision outcomes. The consequence of an outcome is expressed in terms of the relative regret that would be experienced by the decision maker should the outcome actually occur.

3.1.7 <u>Decision outcome criteria</u> - A list of q criteria $(C_1, C_2, \ldots C_q)$, each appropriately labeled, by which the decision maker would judge the relative regret associated with the decision outcome.

3.1.8 <u>Criteria weights</u> - A vector of q weights $(w_1, w_2, \ldots w_q)$ associated with the q criteria, such that w_i represents the relative contribution of criterion C_i. Criteria weights are expressed numerically as a percentage of the whole, e.g., as 60%.

3.1.9 __Regret__ - Regret is a measure of the consequence of a decision outcome. The total regret assigned to a decision outcome is a weighted linear combination of the individual criteria regrets. For each criterion (C_i) and for each decision outcome (D_j, E_k), the user must specify a value of regret (r_{ijk}). A regret is a number between 0 and -1, inclusive, that represents the relative degree of dissatisfaction that the decision maker associates with a particular decision outcome. Zero represents no regret; -1 represents maximum regret. However, in this specification regrets are usually expressed as a percentage of the maximum; e.g., as -30 vice -0.3. Refer to Figure 3-2.

This completes the model format. The decision model is completely and uniquely specified when the elements described above are defined by the user.

3.2 Results of the Model

The input specifications describing the model can be processed to produce the following results.

3.2.1 __Combined value regret matrix__ - A single n x m matrix that displays the total or combined regret associated with each of the decision outcomes. For each outcome (D_j, E_k), the combined regret, $\hat{r}_{jk}$, is obtained by weighting and adding the component regrets contributed by the q criteria, in accordance with the following formula:

$$\hat{r}_{jk} = \sum_{i=1}^{q} w_i\, r_{ijk}.$$

A combined value regret matrix is shown in Figure 3-3.

CRITERION: C_q WEIGHT: w_q

EVENT OUTCOMES			
E_1	E_2	$\cdots$	E_m

r_{q1m}
r_{q2m}
$\vdots$
r_{qnm}

CRITERION: C_2 WEIGHT: w_2

EVENT OUTCOMES			
E_1	E_2	$\cdots$	E_m

$1m$
$2m$
$\vdots$
nm

CRITERION: C_1 WEIGHT: w_1

		EVENT OUTCOMES			
		E_1	E_2	$\cdots$	E_m
DECISION ALTERNATIVES	D_1	r_{111}	r_{112}	$\cdots$	r_{11m}
	D_2	r_{121}	r_{122}	$\cdots$	r_{12m}
	$\vdots$	$\vdots$	$\vdots$		$\vdots$
	D_n	r_{1n1}	r_{1n2}	$\cdots$	r_{1nm}

Figure 3-2

REGRET MATRICES

COMBINED VALUE

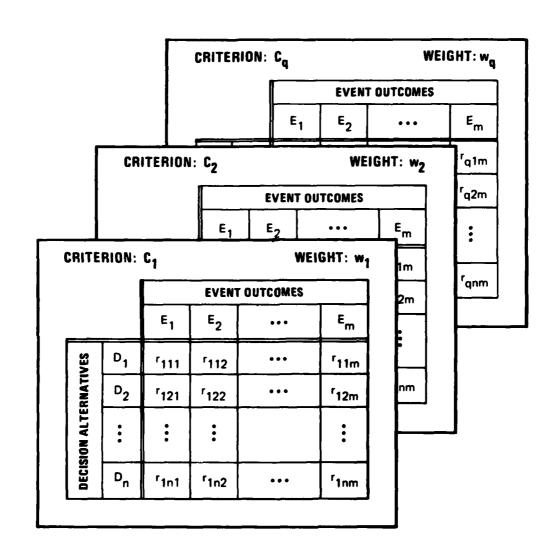|	E_1 (LABEL)	E_2 (LABEL)	E_3 (LABEL)
D_1 (LABEL)	0	-17	-31
D_2 (LABEL)	-9	-9	-17
D_3 (LABEL)	-24	-22	-22
D_4 (LABEL)	-30	-26	-26
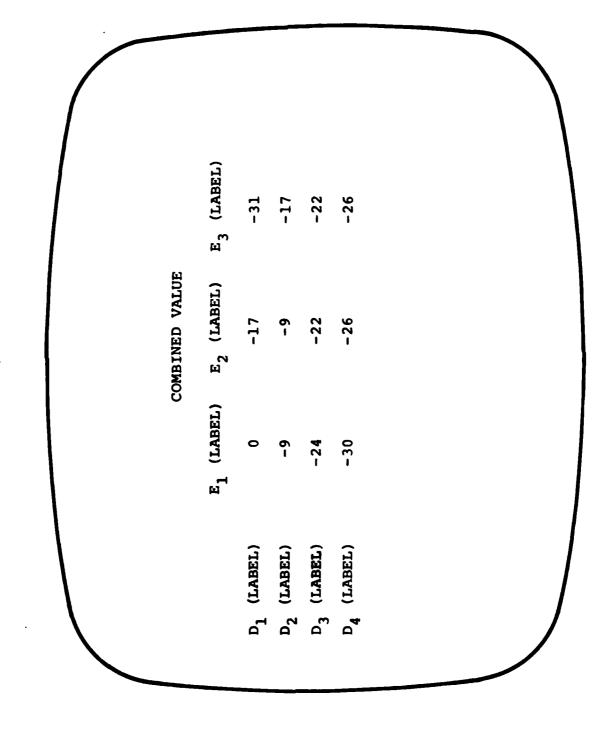
Figure 3-3

A COMBINED VALUE REGRET MATRIX

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3.2.2 <u>Expected value matrix</u> - A single n x m matrix
that displays the weighted expected regret, $\bar{r}_{jk}$, associated
with each decision outcome (D_j, E_k). The expected value
matrix takes into account the relative likelihoods of the
event outcomes. It is obtained from the combined value
regret matrix in accordance with the following formula:

$$\bar{r}_{jk} = p_k \, \hat{r}_{jk}.$$

3.2.3 <u>Expected value vector</u> - A vector of length n
that displays the weighted expected regret, R_j, associated
with each of the n decision alternatives (D_j). The expected
value vector is obtained from the expected value matrix in
accordance with the following formula:

$$R_j = \sum_{k=1}^{m} \bar{r}_{jk}.$$

The expected value matrix and the expected value
vector (total) are displayed together, as shown in Fig-
ure 3-4.

3.3 <u>Sensitivity Analyses</u>

There are two sensitivity analyses that are useful to
the user. Both are based on the expected value vector and
are described as follows:

3.3.1 <u>Threshold matrix</u> - An n x 11 matrix that dis-
plays the eleven expected value vectors generated by either
one of the following operations, at the user's option:

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EXPECTED VALUE

	E_1 (LABEL)	E_2 (LABEL)	E_3 (LABEL)	TOTAL
D_1 (LABEL)	0	0	-4	-4
D_2 (LABEL)	-5	0	-2	-7
D_3 (LABEL)	-12	-1	-3	-16
D_4 (LABEL)	-15	-1	-4	-20
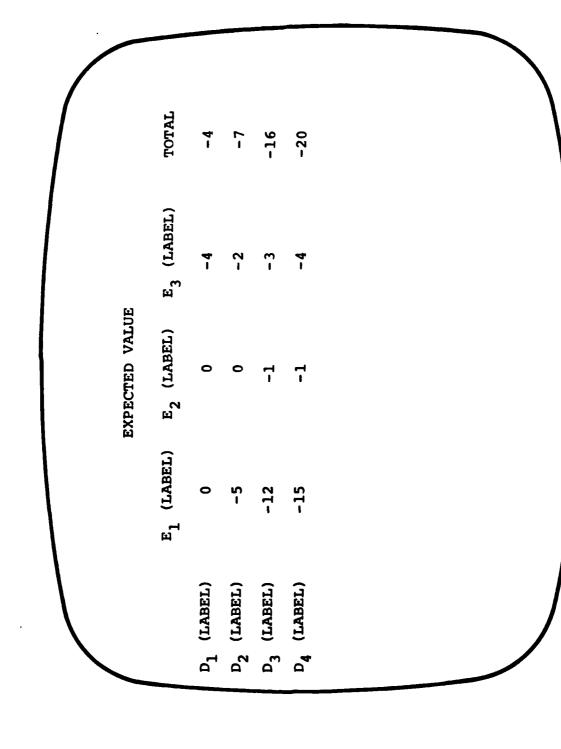
Figure 3-4

AN EXPECTED VALUE MATRIX AND AN EXPECTED VALUE VECTOR

a. Varying the probability of a designated event outcome, E_i, from 0 to 100%, in steps of 10. The other event outcomes, E_j, maintain their proportional relationships with each other.

That is,

$$\Theta_j = \frac{p_j \ (100 - \Theta_i)}{100 - p_i}$$

where

Θ_i = a variable, the test probability of E_i, varied from 0 to 100% in steps of 10;

Θ_j = a variable, the test probability of E_j as Θ_i is varied;

p_i = a constant, the originally specified probability of event E_i;

p_j = a constant, the originally specified probability of event E_j.

b. Varying the weight of a designated criterion (C_i) from 0 to 100%, in steps of 10. The weights of the other criteria (C_j) maintain their proportional relationship with each other in the same manner as do the probabilities described in the preceding paragraph.

That is,

$$W_j = \frac{w_j \ (100 - W_i)}{100 - w_i}$$

where

w_i, w_j = constants--the original criteria weights;

W_i, W_j = variables--the test criteria weights.

In both of the above cases, the least regret displayed in the expected value payoff vector is identified by an asterisk.

Normally, the decision alternative that leads to the decision outcome having the least regret will change as the designated event probability or criterion weight is incremented from 0 to 100%. The points of change are referred to as threshold points and are noted on the matrix. Figure 3-5 shows an example threshold matrix.

3.3.2 **Manually change event probabilities** - The user may generate a test expected value vector that is based on an arbitrarily assigned vector of event probabilities. The user may specify several different probability vectors and note the resultant expected value vectors. An example of the display is shown in Figure 3-6.

3.4 **Reference Gamble**

A reference gamble is a technique designed to assist the user in validating the specified regret values, r_{ijk}. The technique addresses the single vector of regrets associated with one designated criterion, C_i, and one designated event outcome, E_k. Specifically, it assists the user by focusing on the values of regret assigned to the n decision

EXPECTED VALUE WHEN
PROBABILITY OF E_1 (LABEL) IS:

	0	10	20	30	40	50	60	70	80	90	100
D_1 (LABEL)	-57	-52	-46	-40	-34	-29	-23*	-17*	-11*	-6*	0*
D_2 (LABEL)	-51	-47	-42	-38	-34	-30	-26	-21	-17	-13	-9
D_3 (LABEL)	-27	-27	-27	-26*	-26*	-26*	-25	-25	-24	-24	-24
D_4 (LABEL)	-26*	-26*	-27*	-27	-27	-28	-28	-28	-29	-29	-30

Figure 3-5

A THRESHOLD MATRIX

	NONE	P-300	P-2K	NP-2K	NP-6K		
CURRENT PROBABILITIES	52	3	14	17	14		
TRIAL PROBS:	100	10	20	20	40		
NORMALIZED PROBABILITIES	-	53	5	11	11	11	21
IF THESE VALUES ARE CORRECT TYPE GO:	GO						
TRIAL PROBS:	20	30	30	70	100		
NORMALIZED PROBABILITIES	-	8	12	12	28	28	40
IF THESE VALUES ARE CORRECT TYPE GO:	GO						
TRIAL PROBS:	----	----	----	----	----		

A REVIEW OF YOUR PROBABILITY ESTIMATES

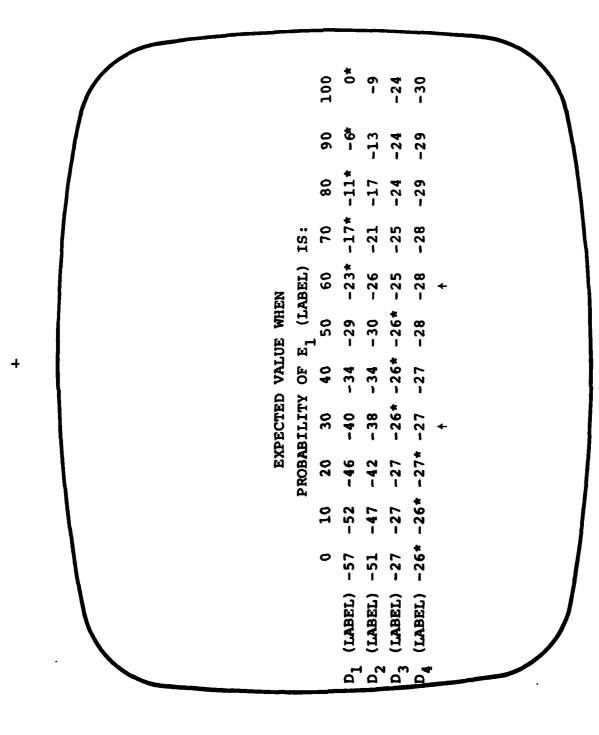|	ESTIMATE #		
	0	1	2
D_1 (LABEL)	-28	-28	-56
D_2 (LABEL)	-29	-30	-52
D_3 (LABEL)	-26	-26	-28
D_4 (LABEL)	-28	-28	-26

Figure 3-6

MANUALLY CHANGED EVENT PROBABILITIES

outcomes resulting from the various decision alternatives, D_j, as they combine with the fixed criterion (C_i) and the fixed event outcome (E_k).

The technique assumes that the greatest regret (r_{max}) and the least regret (r_{min}) in the vector have been correctly specified by the user. Accordingly, the technique addresses only the intermediate values of regret, that is, those that fall between r_{max} and r_{min}.

For each decision outcome of interest (D_j, E_k), the system asks the user to respond to the following question:

Would the user prefer:

a.   a binary gamble in which the best outcome (r_{min}) would occur with probability P and the worst with probability (100% - P), or

b.   obtaining the decision outcome of interest (D_j, E_k) for certain?

The system sets the value of P to 100% initially, so that a rational user would certainly prefer the first option, the gamble, to obtaining the intermediate outcome of interest with certainty. However, as the value of P is decremented in steps of 10%, the user will, at some point, prefer the second option to the reference gamble. At the point of indifference between the two options, the user has established a coherent value of regret for the decision outcome of interest. That regret is equal to the expected value of the reference gamble, or:

$$r_{ijk} = P \times (R_{max}) + (100\% - P)(R_{min}).$$

A sample display is shown in Figure 3-7. User responses are underlined for clarity.

WOULD YOU PREFER TO HAVE CHOSEN
1) D_2(LABEL) (WITH F_3 [LABEL] OCCURRING) FOR CERTAIN
   OR
2) A 100% CHANCE OF D_1 (LABEL) (WITH E_3 [LABEL] OCCURRING) AND
   A 0% CHANCE OF D_3 (LABEL) (WITH E_3 [LABEL] OCCURRING) ?

INDICATE YOUR CHOICE BY TYPING 1 OR 2. 2

WOULD YOU PREFER TO HAVE CHOSEN
1) D_2 (LABEL) (WITH F_3 [LABEL] OCCURRING) FOR CERTAIN
   OR
2) A 90% CHANCE OF D_1 (LABEL) (WITH E_3 [LABEL] OCCURRING) AND
   A 10% CHANCE OF D_3 (LABEL) (WITH E_3 [LABEL] OCCURRING) ?

INDICATE YOUR CHOICE BY TYPING 1 OR 2. 2

WOULD YOU PREFER TO HAVE CHOSEN
1) D_2 (LABEL) (WITH E_3 [LABEL] OCCURRING) FOR CERTAIN
   OR
2) AN 80% CHANCE OF D_1 (LABEL) (WITH E_3 [LABEL] OCCURRING) AND
   A 20% CHANCE OF D_3 (LABEL) (WITH E_3 [LABEL] OCCURRING) ?

INDICATE YOUR CHOICE BY TYPING 1 or 2. 1

YOUR RESPONSES TO THESE QUESTIONS IMPLY THAT YOUR REGRET FOR
D_2 (LABEL) IN THE F_3 (LABEL) COLUMN OF THE C_2 (LABEL) MATRIX
SHOULD BE BETWEEN 80% AND 90% OF THE MAXIMUM REGRET.

Figure 3-7

A REFERENCE GAMBLE ELICITATION

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4.0 OPINT FUNCTIONS

OPINT is designed to perform the basic functions described below. A description of the detailed logical design of the OPINT functions is contained in the manual, <u>Documentation of Decision-Aiding Software: OPINT System Specification</u>, Reference 1.2.3.

4.1 <u>Maintain a Library of OPINT Models</u>

Store various decision models, filed by their associated labels.

4.2 <u>Load an Existing OPINT Model</u>

Display the labels of those models stored in the model library, and permit the user to retrieve any desired model. The loaded model is referred to as the current model.

4.3 <u>Display the Results of the Current Model</u>

Permit the user to examine the structure and content of the current model by displaying:

    a. event probabilities,
    b. criteria weights,
    c. regrets,
    d. combined value regret matrix,
    e. expected value matrix, and
    f. expected value vector.

4.4 <u>Revise the Current Model</u>

Permit the user to make changes to the structure and content of the current model. The user may revise:

a.   event probabilities,

        b.   criteria and criteria weights,

        c.   decision alternatives,

        d.   regrets,

        e.   combined value regret matrix.

4.5   Save the Current Model

    Permit the user to add the current model to the model
library.

4.6   Perform Sensitivity Analyses

    Permit the user to test the sensitivity of the current
model by:

        a.   determining thresholds,

        b.   manually changing probabilities.

4.7   Create a New OPINT Model

    Permit the user to create a new model, which then
becomes the current model. The user creates a model by
specifying the elements listed in Section 3.1. The user may
also use a reference gamble to validate the assigned values
of regret.